5. PRODUCTION, IMPORT/EXPORT, USE, AND DISPOSAL

5.1 PRODUCTION

The earth's crust contains about 2–3 ppm tin, comprising 0.0006% of the earth's crust (Budavari 2001; Bulten and Meinema 1991). The most important tin containing mineral is cassiterite, SnO_2. Other tin minerals are stannite, teallite, cylindrite, and canfieldite. After tin-containing ores are mined, they undergo further separation processing resulting in concentrates containing 70–77% tin by weight, which is almost pure cassiterite, and are ready for smelting (Gaver 1997).

The world's largest producer of tin in 2001 was China (36% of the world total), followed by Indonesia (23%), Peru (17%), Brazil (6%), Bolivia (6%), and Australia (4%). Of the 22 countries that mine tin, these six account for 92% of the world total. Tin has not been mined in the United States since 1993. Production of tin stopped in 1989 at the only U.S. tin smelter at Texas City, Texas. However, the United States is believed to be the world's largest producer of secondary tin. In 2002, about 14,000 tons of tin from old and new scrap were recycled at 3 detinning plants and 65 secondary nonferrous-metal processing plants. The Defense Logistics Agency, which manages the National Defense Stockpile, sold 5,246 metric tons of pig tin from the stockpile in 2001. The Steel Recycling Institute stated that the steel can (tin-plated) recycling rate in the United States in 2001 was 58%. Tin is recovered, in addition to steel, in can recycling (Carlin 2001, 2003). Production of organotin compounds was 5,000 tons in 1955 and approximately 35,000 tons in 1985 (Fent 1996). More recent production numbers for organotin compounds could not be located. Current U.S. manufacturers of selected tin compounds are given in Table 5-1.

5.2 IMPORT/EXPORT

U.S. consumption of primary and secondary tin was 34,200 and 6,990 metric tons, respectively, in 2001 and is estimated as 37,000 and 9,000 metric tons, respectively, for 2002. U.S. imports of refined tin in 2001 totaled 37,500 metric tons and were mainly from Peru, followed by China, Bolivia, Brazil, and Indonesia. Tin imports for 2002 are estimated at 37,000 metric tons. Major imports of tin include unwrought metal, waste and scrap, and unwrought tin alloys. Tin exports of refined tin were 4,350 metric tons in 2001 and are estimated at 3,500 metric tons for 2002 (Carlin 2001, 2003). In 2002, U.S. imports

Table 5-1. Current U.S. Manufacturers of Selected Tin Compounds[a]

Company	Location
Inorganic tin compounds	
Tin(II) chloride	
ATOFINA Chemicals, Inc. Specialty Chemicals Division	Carrollton, Kentucky
Tin(II) fluoride	
Ozark Fluorine Specialties, Inc.	Tulsa, Oklahoma
Tin(IV) oxide	
Engelhard Corporation, Appearance and Performance Technologies	Elyria, Ohio
Ferro Corporation, Coatings, Colors, and Ceramics Group Electronic Materials Division	Penn Yan, New York
Tin(II) fluoroborate	
Atotech USA Inc.	Rock Hill, South Carolina
General Chemical Corporation	Claymont, Delaware
OMG Fidelity, Inc.	Newark, New Jersey
Solvay Fluorides Inc.	St. Louis, Missouri
Methyltin compounds	
Dimethyltin dineodecanoate	
Gelest, Inc.	Tullytown, Pennsylvania
Tetramethyltin	
Clariant Life Science Molecules (America) Inc.	Gainesville, Florida
Gelest, Inc.	Tullytown, Pennsylvania
Butyltin compounds	
Dibutyltin acetylacetonate	
MacKenzie Company	Bush, Louisiana
Dibutyltin bis(2,4-pentanedionate)	Tullytown, Pennsylvania
Gelest, Inc.	
Dibutyltin bis(2-ethylhexanoate); Dibutyltin bis(isooctyl) maleate; Dibutyltin bis(isooctyl mercaptoacetate); Dibutyltin bis(isopropyl maleate); Dibutyltin bis(n-lauryl mercaptide); Dibutyltin dibutoxide; Dibutyltin dimethoxide; Dibutyltin disalicylate; Dibutyltin mercaptopropionate; Dibutyltin sulfide; Tributyltin fluoride	
ATOFINA Chemicals, Inc. Specialty Chemicals Division	
	Carrollton, Kentucky
Dibutyltin chloride; Dibutyltin oxide; Bis(tributyltin) oxide;	
ATOFINA Chemicals, Inc. Specialty Chemicals Division	Axis, Alabama Carrollton, Kentucky
Dibutyltin diacetate	
ATOFINA Chemicals, Inc. Specialty Chemicals Division	Carrollton, Kentucky

Table 5-1. Current U.S. Manufacturers of Selected Tin Compounds[a]

Company	Location
Ferro Corporation Performance and Fine Chemicals Group Polymer Additive Division	Walton Hills, Ohio
Dibutyltin difluoride	
ATOFINA Chemicals, Inc. Specialty Chemicals Division	Carrollton, Kentucky
Atotech USA Inc.	Rock Hill, South Carolina
Dibutyltin dilaurate	
ATOFINA Chemicals, Inc. Specialty Chemicals Division	Carrollton, Kentucky
Ferro Corporation Performance and Fine Chemicals Group Polymer Additives Division	Walton Hills, Ohio
Johnson Matthey, Inc. Alfa Aesar	Ward Hill, Massachusetts
Dibutyltin maleate	
ATOFINA Chemicals, Inc. Specialty Chemicals Division	Carrollton, Kentucky
Ferro Corporation Performance and Fine Chemicals Group Polymer Additive Division	Walton Hill, Ohio
Tributyltin chloride	
ATOFINA Chemicals, Inc. Specialty Chemicals Division	Axis, Alabama Carrollton, Kentucky
Tributyltin hydride	
Johnson Matthey, Inc. Alfa Aesar	Ward Hill, Massachusetts
Sigma-Aldrich Fine Chemicals	Plant location not specified
Tetrabutyltin	
ATOFINA Chemicals, Inc. Specialty Chemicals Division	Axis, Alabama
Octyltin compounds	
Dioctyltin S,S'-bis(isooctylmercaptoacetate); Dioctyltin dichloride; Dioctyltin maleate	
ATOFINA Chemicals, Inc. Specialty Chemicals Division	Carrollton, Kentucky
Dioctyltin dilaurate	
ATOFINA Chemicals, Inc. Specialty Chemicals Division	Carrollton, Kentucky
Gelest, Inc.	Tullytown, Pennsylvania
Dioctyltin oxide	
ATOFINA Chemicals, Inc. Specialty Chemicals Division	Carrollton, Kentucky Axis, Alabama
Tetraoctyltin	
ATOFINA Chemicals, Inc. Specialty Chemicals Division	Axis, Alabama
Phenyltin compounds	
Diphenyltin chloride; Diphenyltin oxide; Triphenyltin fluoride	
ATOFINA Chemicals, Inc. Specialty Chemicals Division	Carrollton, Kentucky

[a]Derived from SRI 2003. SRI reports production of chemicals produced in commercial quantities (defined as exceeding 5,000 pounds or $10,000 in value annually) by the companies listed.

for consumption of dibutyltin oxide, tetrabutyltin, and other organotin compounds were approximately $4.89x10^5$, $3.40x10^5$, and $27.3x10^5$ kilograms, respectively (ITA 2003).

5.3 USE

The major uses of tin in 2002 were: cans and containers, 27%; electrical, 23%; construction, 10%; transportation, 10%; and others 30% (Carlin 2001). Tinplate is used in food packaging, aerosol containers, and decorative applications. Various tin alloys are important, including bronze and pewter. Tin readily forms alloys with other metals and imparts hardness and strength. Tin is an important component of solders, since it wets the base metal by alloying with it (Gaver 1997).

Inorganic tin compounds are used in the glass industry, where they are added to strengthen the glass. Inorganic tin compounds also serve as the base for the formulation of colors, as catalysts, and in perfumes and soaps (WHO 1980). Tin(IV) oxide (SnO_2) is used in the ceramics and glass industries, as well as a polishing agent and as a catalyst (Kroschwitz and Howe-Grant 1997). It is also used to produce milky or colored glass and in the formulation of fingernail polish (Windholz 1983). Tin(IV) chloride ($SnCl_4$) is often used as the starting material for the production of organotin compounds. Tin(II) fluoride (SnF_2) is added to toothpastes as an anticaries agent. Tin(II) chloride ($SnCl_2$) is the most important inorganic tin compound. It is used as an industrial reducing agent and in tin electroplating. Tin(II) chloride is also used as a food additive, (e.g., as a preservative and a color-retention agent). Tin(II) fluoroborate ($Sn(BF_4)_2$), which is not isolated as a solid but is only found in solution, is an important chemical in electroplating. The consumption of inorganic tin compounds is lower than that of organotin compounds (Graf 1996; Kroschwitz and Howe-Grant 1997).

Examples of commercially important organotin compounds include tetraorganotins (R_4Sn), triorganotins (R_3SnX), diorganotins (R_2SnX_2), and monoorganotins ($RSnX_3$). The organotin compounds of commercial importance have R groups equal to methyl, butyl, octyl, cyclohexyl, phenyl, or neophyl. The anionic X groups are commonly halides, oxide, hydroxide, carboxylates, or mercaptides. Tetraorganotin compounds are mainly used in the production of tri-, di-, and monoorganotin compounds. Tri- and diorganotin compounds are the most important classes of organotin compounds. Triorganotin compounds are used as industrial biocides, agricultural chemicals, wood preservatives, and marine antifouling agents. Diorganotin compounds are used as polyvinyl chloride (PVC) stabilizers and as polyurethane foam and esterification catalysts. Monoorganotin compounds are also used as PVC stabilizers, as well as in the treatment of glass (Kroschwitz and Howe-Grant 1997).

The major use of organotin compounds is for heat stabilization of PVC, which represents approximately two-thirds of the global consumption (Sadiki and Williams 1999). It was estimated that in 1981, the U.S. consumption of organotin compounds as PVC stabilizers was 10,650 tons, approximately 27% of the world market (Kroschwitz and Howe-Grant 1997). Organotin compounds used as PVC stabilizers include butyl-, octyl-, and methyltin compounds. Octyl- and methyltin compounds are used in PVC for food packaging. In the United States, the organotin compounds that are used predominantly as PVC stabilizers are methyltins (about 50% of the market) and butyltins (40%), with octytin compounds making up the remainder. In Asia, methyltins (50%) and octyltins (40%) and in Europe, octyltins (60%) and butyltins (30%) are the most widely used organotin compounds as PVC stabilizers (Leaversuch 1999). Tributyltin compounds are also used as slimicides on masonry, as disinfectants, and as biocides for cooling systems, power station cooling towers, pulp and paper mills, breweries, leather processing, and textile mills (WHO 1990).

The use of triorganotin compounds as marine antifoulants has been restricted by the Organotin Antifouling Paints Control Act (June 16, 1988), which limits the type of vessel on which these paints can be used, and limits the use of tributyltin paints to those that have laboratory tested release rates of $\leq 4\ \mu g/cm^2/day$ (Cardwell et al. 1999a). France was the first country to adopt restrictions in 1982, and now the majority of industrialized countries have adopted restrictions on the use of tributyltin containing paints on vessels <25 meters in length, and include, in addition to France and the United States, the United Kingdom, Canada, New Zealand, Australia, and the European Union (Birchenough et al. 2002).

5.4 DISPOSAL

Tin-containing wastes in the form of salts, slags, and muds are generated as a result of smelting, refining, and detinning processes. Solid wastes containing tin are generated by both domestic and industrial users of containers. Tin-containing wastes may be incinerated or disposed of in landfills (WHO 1980).

Inorganic and organic tin compounds may be disposed of in sealed containers in a secured sanitary landfill (NIOSH/OSHA 1981).

Tin is not listed as a hazardous waste constituent by the EPA and therefore, its disposal is not restricted by federal land disposal restrictions. No data were located regarding the amounts of tin disposed of by any means or trends in the disposal of tin.